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Development of Amsinckia Grandiflora Restoration Techniques

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Development of *Amsinckia grandiflora* Restoration Techniques

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Amsinckia grandiflora is federally listed endangered species native to California valley grasslands. Demographic data were collected from marked plants found in experimental plots. A grass-selective herbicide was applied to a subset of the plots monitored. The height and survivorship data suggest that competitive pressure is greater in untreated plots. The demographic data will be used in the restoration of existing and creation of new *A. grandiflora* populations.

INTRODUCTION

Amsinckia grandiflora (Gray) Kleeb. ex Greene (Boraginaceae) is an annual forb, which is part of the California winter annual grassland. It is a federally listed endangered species that is found in the Altamont Hills of the Diablo Range, about 50 miles east of San Francisco, California, on or near Site 300. Site 300 is a Lawrence Livermore National Laboratory high-explosive test facility, operated by the University of California for the U.S. Department of Energy. *A. grandiflora* is known from three natural populations that occur on steep, well drained, north facing slopes of intermediate (300 m) elevations (Carlsen, 1996). One of these populations may have been extirpated in a landslide during the winter of 1997.

Historically, *A. grandiflora* is believed to have occurred in native perennial bunch grass communities, sometimes referred to as California valley grasslands. It is endemic to the northern Diablo Range, which is part of the inner South Coast Range of California (U.S. DOI, 1997). The introduction of exotic Mediterranean annual grasses during European settlement has resulted in the displacement of native perennial and annual grassland species. The modified communities are referred to as California winter annual grasslands (Carlsen, 1996). Changes in historic grazing and fire patterns have also contributed to the conversion of the original California valley grasslands to the exotic California winter annual grasslands (U.S. DOI, 1997).

Several studies have suggested that the decline of *A. grandiflora* is due in part to competitive suppression by exotic grass species. Pavlik et al. (1993) found that competition with exotic grasses reduced fecundity in an experimental population of *A. grandiflora*. Furthermore, the application of a grass-specific herbicide to the Site 300 Drop Tower native population over several years resulted in a ten-fold increase in the number of plants in that population (Pavlik, 1995). Carlsen (1996) found that reproductive success of *A. grandiflora* was greater in a community dominated by intermediate densities of perennial grasses compared to one composed of exotic annual grasses. The recovery strategy developed by the U.S. Fish and Wildlife Service recognizes that the restoration of native perennial bunchgrass communities is essential to the recovery of *A. grandiflora* (U.S. DOI, 1997).

This paper outlines research activities conducted during the 1997/1998 growing season. The purpose of this research is to develop techniques that can be used in the restoration of *A. grandiflora* and the associated perennial bunchgrass community. The goal of this field season was to determine the response of *A. grandiflora* to the application of a grass-selective herbicide. The grass-selective herbicide Fusilade has been used as an interim method of controlling competition from non-native annual grasses.

METHODS AND MATERIALS

Demographic Monitoring

Germination of *A. grandiflora* in the Drop Tower experimental population (located at Site 300) was observed on 21 Nov. 1997. On 11 Dec. 1997, six 0.64 m^2 plots were established in the experimental population. We attempted to mark ten *A. grandiflora* seedlings in each plot, but were unable to find exactly ten in every plot. Positive field identification between different *Amsinckia* species is not possible at the seedling stage. As they flower, *A. grandiflora* can be differentiated from congeneric species and sample sizes were adjusted to reflect the correct number of *A. grandiflora* plants. The final number of marked plants in each plot varied from five to eleven individuals. It is also possible that congeneric individuals that died before flowering (precluding correct identification) were included in the survivorship and height data sets.

The plants were marked by looping a piece of string around the base of each seedling and placing a pin flag next it. This ensured that the same plants were monitored on each observation date. Height and survivorship of the plants were measured on 16 Dec. 1997, 23 Jan. 1998, 11 Feb. 1998, 6 Mar. 1998, 1 Apr. 1998 and 15 Apr. 1998.

Herbicide Treatment

The herbicide treatment was conducted on 29 Jan. 1998. Ninety milliliters (mls) of Fusilade concentrate and 10 mls of surfactant were dissolved into 7.6 L of water. The herbicide solution was applied at an approximate rate of 150-200 mls/m^2. Three of the demographic plots were treated with herbicide and three were left untreated. Herbicide was applied to the plots that contained the highest exotic grass density while the untreated plots contained the highest native bunchgrass density. Forb, grass, and overall herbaceous cover were estimated in all six plots on 6 Mar. 1998 and 25 Mar. 1998.

Data Analysis

The data from the herbicide study were analyzed according to treatment. The percent cover values given for each treatment represent the mean and standard error of the individual plot estimates. Survivorship was calculated in a two-step process. First, percent survival was calculated as the number of surviving plants divided by the total number of plants in each plot. Then, the mean of the individual plot percentages was found for each treatment. A similar process was used to calculate the mean height of the marked plants. The mean height of the individual plants was calculated within each plot. The mean of these values was then calculated, again according to treatment. Only the second mean values are reported here. The standard error was also calculated for both survivorship and height.

Statistical analyses were conducted using the GLM (General Linear Model) procedure of SAS (SAS, 1990). All percentage data were arcsine transformed prior to statistical analysis (Krebs 1989). Results were considered significant if the alpha value was less than or equal to 0.05.

RESULTS

Figure 1 shows cover estimates made following the application of herbicide. Although differences observed between dates may be an artifact of sampling error, it did appear that the effects of the herbicide on cover increased over time. We are confident that the cover estimates are consistent within each sampling date. Because of this, only values from the same date were compared in the statistical analysis. Grass cover and total plant cover were greater in the untreated plots than in the treated plots for both dates. With the exception of forb cover estimates from 25 Mar. 1998, the cover estimate values were significantly different between treatments.

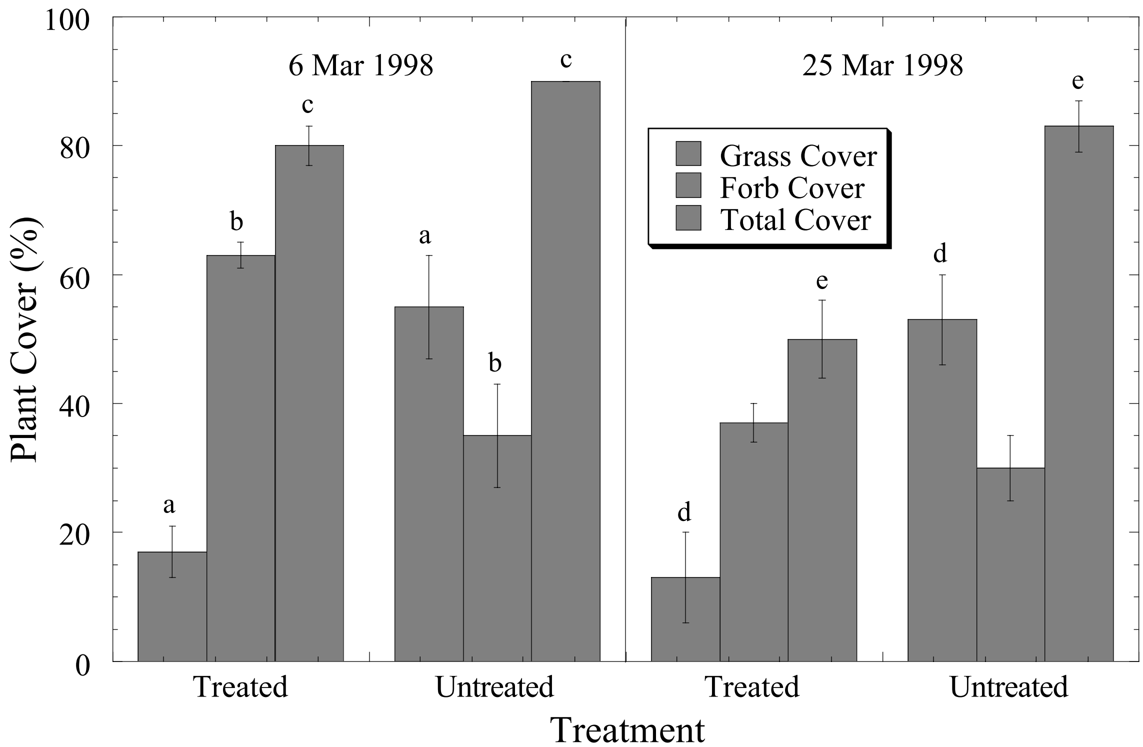

Figure 1. Plant cover estimates for *A. grandiflora* experimental population plots for 6 Mar. 1998 and 25 Mar. 1998. Bars represent one standard error, n=3. Treatments with the same letters are significantly different at $p<0.05$.

Figure 2 shows survivorship of marked *A. grandiflora* plants for treated and untreated plots. By the end of the study, survivorship values for marked plants were less in the untreated plots than in the treated plots (5.56 ± 5.56% for untreated plots, 30.68 ± 16.11% for treated plots). However, the difference in values between treatments is not statistically significant.

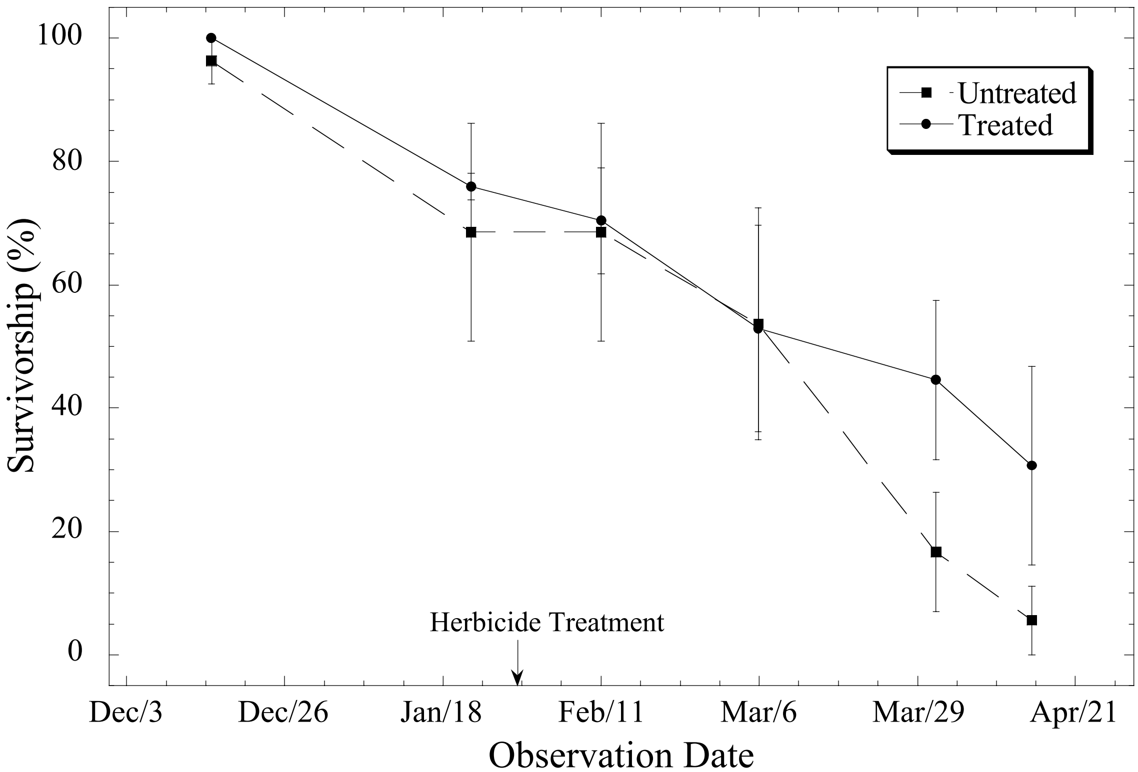

Figure 2. Survivorship of *A. grandiflora* plants marked on 11 Dec. 1997. Bars represent one standard error, n=3.

The mean height of marked *A. grandiflora* plants in the treated versus the untreated plots is shown in Figure 3. The mean height of marked plants in the untreated plots was greater than that observed in the treated plots. As was the case for survivorship, the difference in mean height between treatments was not observed until the end of the study (25.6 ± 0 cm for untreated plots, 18.43 ± 0.42 cm for treated plots) and is not statistically significant.

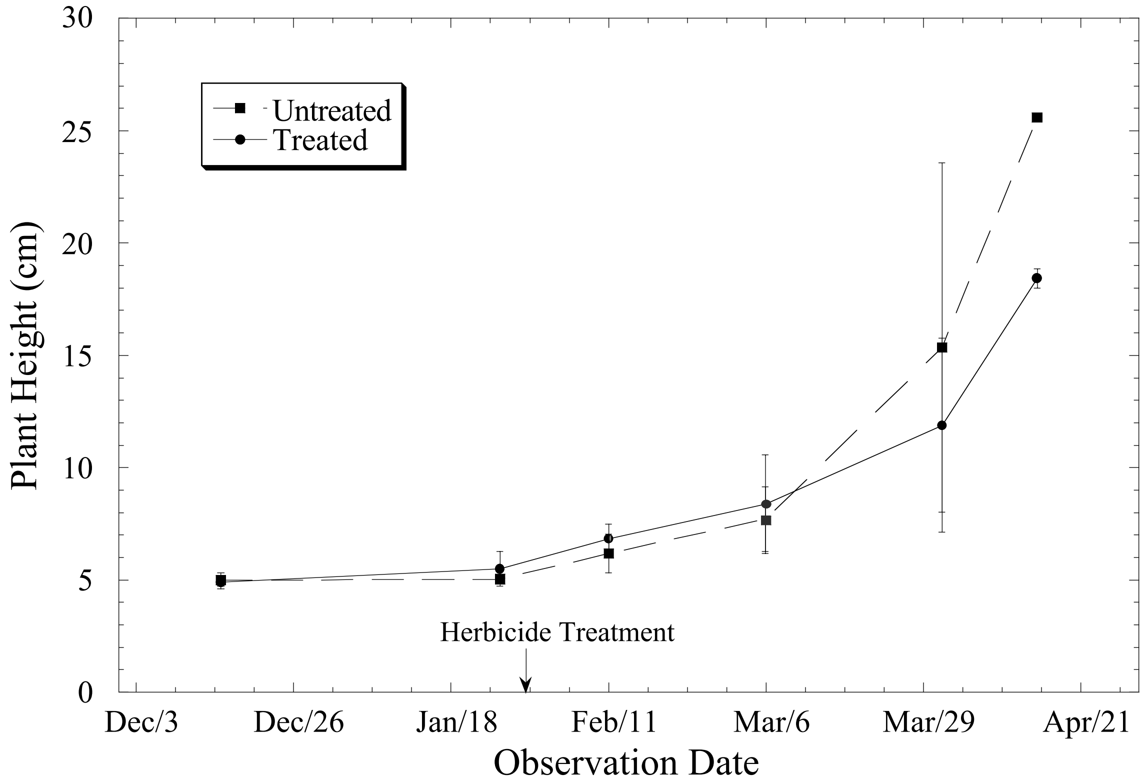

Figure 3. Mean height of *A. grandiflora* plants marked on 11 Dec. 1997. Bars represent one standard error, n=3.

DISCUSSION

The greater grass cover and total cover observed in the untreated plots suggest greater competition for resources in those plots. It is likely that competitive effects observed in this study are the result of both inter- and intra-specific competition for multiple resources. This study was not designed to determine which resources are limiting. Because of the dense canopy created by precocious growth of annual grasses, competition for light is probably a major determinant of growth and survivorship in the understory.

The number of plants sampled was reduced considerably over the course of the study period, due to mortality and exclusion of congeneric individuals. Differences between the mean values were not statistically significant, but this may be the result of very small sample size. However, we did observe trends in growth and survivorship that warrant further study.

If the trends observed are real, it is probable that the decreased survivorship of marked *A. grandiflora* plants in the untreated plots is the result of increased competition in those plots. The increase in the mean height of marked plants in the untreated plots could be attributed to differential survivorship or to a morphological response. Increased competition in the untreated plots may have allowed only the largest *A. grandiflora* plants to survive, whereas reduced competition in the treated plots would have allowed smaller individuals to survive. The increased height of *A. grandiflora* plants in the untreated plots may also be the result of hyperelongation of the stems. Stem elongation allows plants to escape reduced light levels such as those found in the understory of the untreated plots.

The lower survivorship recorded in the untreated plots supports the hypothesis that competition from grasses results in decreased persistence of *A. grandiflora*. This demographic trend has been observed in other studies as well (Carlsen 1996, Pavlik, et al. 1993). Thus, competition from exotic grasses must be reduced in the early stages of *A. grandiflora* reintroduction in order to allow the introduced populations to reach self-sustaining levels.

However, limiting all competitive pressure would fundamentally change the selective environment to which *A. grandiflora* is exposed. Previous work suggests that a native perennial bunchgrass community maintained at intermediate densities would provide an environment less hostile to *A. grandiflora* without completely eliminating competition from grasses (Carlsen, 1996). Furthermore, during the course of the study we observed that the native perennial bunchgrasses seemed to tolerate the herbicide treatment better than the exotic annuals. While more rigorous study of this response is warranted, dilute solutions of grass-specific herbicides may prove useful in the reintroduction of *A. grandiflora* and the associated perennial bunchgrass community.

CONCLUSION

Restoration of an extremely rare species such as *A. grandiflora* is an ongoing, labor intensive process. The success of this restoration effort requires continued commitment to understanding not only the ecology of *A. grandiflora* but of the native perennial bunchgrass community as well. We will continue to examine alternative methods for restoration of both, particularly the effects of fire on community composition. Preservation of *A. grandiflora* and the associated native bunchgrass community is likely to prove beneficial to other species endemic to the California valley grasslands. The methods developed here may also prove useful in the restoration of other endangered plant species.

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